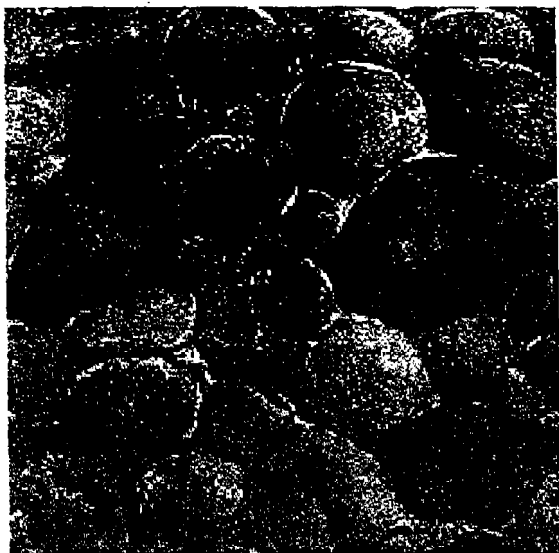


# ◆ COARSE SEDIMENT SUPPLY



## INTRODUCTION

Natural sediments of streams, rivers, and estuaries consist of mineral and organic silts, sands, gravel, cobble, and woody debris. These materials naturally enter, deposit, erode, and are transported through the Bay-Delta and its watershed. Sediment, like water, is one of the natural building blocks of the ecosystem. Many other ecological processes and functions, and habitats and species require specific types and amounts of sediment and the habitats sediments create. Gravel, for example, is important for maintaining spawning habitat for salmon and steelhead, and as habitat for stream invertebrates. Finer sediments are important in the natural development of riparian and wetland habitats. Major factors that influence the sediment supply in the Bay-Delta and its watersheds include many human activities such as dams, levees, and other structures, dredging, and gravel and sand mining.

River-transported sediments are an essential component of the physical structure and nutrient base of the Bay-Delta ecosystem and its riverine and tidal arteries. The size, volume, and seasonal timing of sediments entering the riverine and estuarine systems should be compatible with both natural and altered flow regimes. Sediment transport should match channel and floodplain characteristics of individual rivers, streams, and tidal sloughs. A

specific sediment management objective is to redistribute sediment in the watersheds and valley components of the ecosystem. An appropriate level, rate, and size of sediment should be redistributed to match specific habitat requirements and ecological functions.

## RESOURCE DESCRIPTION

The coarse sediment supply is highly variable between the streams and tidal sloughs of the Sacramento and San Joaquin Rivers and Bay-Delta ecosystems. Part of the reason is differences in soils and geofluvial morphology of the watersheds. Other factors include difference in runoff patterns and watershed characteristics. Human activities and development may be important factors. Large dams deprive most of the major rivers entering the Sacramento-San Joaquin Valley of their primary source of sediment from the upper watersheds. Upper watershed sediment supplies have been altered by increased human use and habitation in areas previously only influenced by natural processes of fire, flood, and mass wasting.

Alluvial sediment is stored in the valley floodplains along rivers, but much of this natural supply is no longer available to rivers and streams because of extensive hardening of banks (e.g., rip-rap) to protect stream-side levees, orchards, and cropland. Some individual streams have an excess of fine sediment, such as the lower Feather River that is still affected by an oversupply of sand from the hydraulic mining era. Within the Delta, rivers and sloughs appear to suffer from a net loss of channel sediment resulting in the reduction or disappearance of midchannel islands and shallow shoal habitats. This is believed to be caused by a combination of reduced sediment supply from rivers, historic loss of Delta floodplains (reclamation of formerly extensive tule islands for agricultural uses), high velocity tidal currents, wind wave and boat wake erosion of unprotected, artificially steep banks, and channel dredging to maintain shipping routes and floodway capacity.

Land use has also altered natural sediment supplies in Central Valley watersheds. During the gold rush, natural sediment supplies in the Central Valley were



greatly altered by extensive hydraulic and dredge mining on the western Sierra Nevada streams (especially the Yuba, Feather, American, lower Sacramento, and San Joaquin rivers and their tributary watersheds). Sediment from mining in the late 19th Century greatly exceeded the amounts that rivers were able to transport. Rivers became overloaded with sediment, causing deposition and flooding in valley towns and farms. Fine sediments pulsed quickly through the river systems, but the coarser sediments moved more gradually. By the late 20th Century, most riverbeds had returned to pre-Gold Rush elevations because riverflows had cut through the old placer mining debris deposits stored along the banks. Some rivers and creek valleys still contain "debris dams" (e.g., Daguerre Point Dam on the Yuba River) built a century ago in an attempt to keep placer mining sediment from spreading into streambeds of the valley and causing flooding of cities and farmlands.

Natural sediment recruitment and transport in the Central Valley are tied to streamflow. Most sediment is transported and deposited during winter and spring runoff events. Typically, bars, shoals, and braided deltas form or expand as floodwaters decline and stabilize during the dry season. Flowing water rearranges and sorts sediment (sand, silt, and clay particles) and bedload (cobble and gravel) to create the structural support for many important habitats, including fish spawning gravels, growth medium (substrate) in which riparian forests germinate and establish, and loamy floodplains that support oak woodland and grasslands. Transporting heavier cobble and gravel helps rivers dissipate stream energy, and the formation of heavy cobble bars shields the riverbed from excessive erosion and incision.

Shallow shoals of fresh sediment form along Bay-Delta rivers and sloughs by replacing sediment lost to wave action and tidal currents. The fresh sediment creates new substrate for tule marsh and sustains shallow-aquatic and tidal-mudflat habitats. Fine organic particles and suspended mineral sediment also provide essential nutrients (e.g., carbon, nitrogen, phosphorus, and iron) that support algae and phytoplankton at the base of the foodweb. High concentration of suspended sediment (high turbidity) limits growth of aquatic plants and algae by reducing sunlight penetration.

Constructed features and disturbance factors that eliminate, reduce, or alter the amount, distribution, and timing of natural sediment sources include:

- reservoirs behind medium and large dams that capture the sediment supply from the watershed;
- levees that prevent deposition of fine sediments in the floodplain alongside rivers and increase sediment scour and transport within the river channel by forcing deeper, more erosive floodflows;
- sand and gravel mining in channels and active lower floodplains of rivers and smaller tributaries that deplete the natural supply to downstream sites;
- bank protection and channelization that alters sediment transport, reduce natural bar and riffle formation, and prevent natural bank erosion and gravel and sediment releases to the river; and
- dam-regulated reduction of the magnitude and duration of average peak flows during winter and spring that reduce the ability of a river to transport bedload entering the river from tributary sources.

Sediment transport and deposition processes of the ecosystem have been significantly modified. Construction of the Sacramento River, San Joaquin River, and Delta levees and bypass systems in the early 20th century allowed Central Valley settlements and California agriculture to expand. The original levee system of the Sacramento River was built to bypass excessive floodflows, maintain sufficient channel depth for river navigation, and carry the heavy loads of sediments deposited into the Central Valley by hydraulic gold mining in the mountains and foothills.

The levees isolated rivers from their natural floodplains and separated the Bay-Delta from the extensive freshwater and saline emergent wetlands and secondary sloughs that became the agricultural "islands" we know today. River flows have sufficiently sluiced most of the sediment past the river floodplains and Delta and out to San Francisco Bay. Some of the sluiced sediment was deposited in deeper channels that now require dredging.



The natural supply of gravels and sediments entering the rivers and dams and reservoirs severely reduced streams. Construction of the State and federal dam system occurred between the 1930s (e.g., Shasta Dam) and 1970s (e.g., New Melones and New Don Pedro Dams). Although dams provide water supply and flood control benefits, they drastically reduced the natural sediment supply to Central Valley river floodplains and the Bay-Delta. Dams captured all the bedload and most of the finer sediment. Many smaller dams have filled to capacity with sediment.

The absence of sediment below dams and the confinement of rivers into narrow, leveed corridors triggered channel incision and bank erosion. Incision and erosion threatened the integrity of the levee system, leading to ongoing efforts to armor riverbanks and levees with rock riprap. Implementation of these actions further reduces the natural sediment supply of rivers.

Confining rivers and hardening banks removes the major remaining supply of gravel and sediment below dams. The lack of gravel and sediment inhibits bank erosion. Preventing or reducing bank erosion also reduces the establishment of instream woody cover (a component of shaded riverine aquatic cover) because the erosion required to topple trees into the channel no longer occurs.

The sediment deficit and high transport efficiency of the primary Delta channels, combined with wave-wash erosion, are causing the progressive disappearance of remnant tule and willow midchannel islands and shoals. These conditions prevent the replenishment of deposits that support mudflat, emergent wetlands, and willow scrub habitats. Lack of sediment and high velocities are also undermining the submerged toe of levees along Delta islands.

Immediately downstream of dams, where water temperature is often cool enough to support spawning fish populations, the release or uncontrolled spills of "clean, hungry" dam water removes the spawning gravels from the channel, armors the channelbed with more resilient (larger-sized) cobble and boulders, and erodes the fine sediment that would normally support riparian trees and shrubs along the banks. Scoured and armored river beds lack spawning habitat for salmon and steelhead forced to

spawn and rear below dams that have cut them off from natural upstream habitats.

Further downstream, natural sediment and erosion patterns of the floodplain have been altered by river channelization. Only the Butte basin flood overflow area and the Sutter and Yolo bypasses support physical sedimentation processes that roughly approximate a natural floodplain. However, flood conveyance capacity, intensive farming in the bypasses, and flood easement restrictions do not allow the remnant floodplains to support natural habitats. Floodplain habitats such as emergent marsh, cottonwood-willow riparian forest, or valley oak woodland thrive in the fine-textured alluvial deposits. A few notable natural habitats do exist. These include Sutter National Wildlife Refuge, the new Yolo Basin Wildlife Management Area, and some large privately managed waterfowl habitats in the Butte basin.

Gravel mining in Central Valley river channels has also interrupted natural sediment supplies of the rivers. In-channel sand and gravel mining reduces downstream physical habitat and triggers incision of the channelbed both upstream and downstream. Large in-channel and low-floodplain pits are often excavated to a depth lower than the stream channel, such as occurs on the eastside tributaries of the San Joaquin River. These pits often "capture" the river. This creates additional ecosystem disturbances by trapping bedload gravel, causing the river alignment to suddenly shift, exposing outmigrating juvenile salmon and steelhead to increased predation, and stranding of outmigrating juvenile salmon and steelhead in isolated backwater ponds when the river recedes.

## ISSUES AND OPPORTUNITIES

### CHANNEL DYNAMICS, SEDIMENT TRANSPORT, AND RIPARIAN VEGETATION.

There is growing recognition that dynamic river channels, free to overflow onto floodplains and migrate within a meander zone, provide the best riverine habitats. The dynamic processes of flow, sediment transport, channel erosion and deposition, periodic inundation of floodplains, establishment of riparian vegetation after floods, and ecological succession create and maintain the natural channel and bank conditions favorable to salmon and other important species. These processes also provide important inputs of food and submerged woody



substrates to the channel. The most sustainable approach to restoring freshwater aquatic and riparian habitats is by restoring dynamic channel processes; however, restoration of natural channel processes is now hampered by the presence of levees and bank protection along many miles of rivers. Below reservoirs, the reductions in high flows, natural seasonal flow variability, and supply of sand and gravel have further exacerbated the constraining effect on rivers with levees and rock banks. It is therefore a priority to identify which parts of the system still have (or can have) adequate flows to inundate floodplains and sufficient energy to erode and deposit, and to identify floodplain and meander zone areas for acquisition or easements to permit natural flooding and channel migration. Sediment deficits from in-channel gravel mining should also be identified and the feasibility or efficacy of augmenting the supply of sand and gravel in reaches below dams should be evaluated.

**OPPORTUNITIES:** Mimic natural flows of sediment and large woody debris. Dams disrupt the continuity of sediment and organic-debris transport through rivers, with consequent loss of habitat, and commonly, river incision, downstream. In some cases, such as Englebright Dam on the Yuba River, the feasibility of dam removal should be evaluated as a sustainable solution to reestablishing continuity of sediment and debris transport, as well providing access to important spawning and rearing areas. Most dams, however, cannot be removed, so methods must be sought to reestablish continuity of sediment and wood transport with the dam in place. Coarse sediment can be artificially added below dams to at least partially mitigate for sediment trapping by the dam and ameliorate the impacts of sediment-starved flows. This approach has been successfully used in Europe, using sediment from natural (landslide) and artificial sources (injected from barges). On the River Rhine, enough gravel and sand are added below the lowest dam to satisfy the present sediment transport capacity of the Rhine to prevent further incision of the bed (an average of over 200,000 cubic yards annually). On the Sacramento River, gravels have been added at a rate much below the river's transport capacity so they are vulnerable to washout at high flows. A more sustainable approach would be to add gravel (and sand) on a regular basis and at a much larger scale to better mimic natural sediment loads and therefore provide the sediment from which the

river would naturally create and maintain spawning riffles. This latter approach requires a large commitment of resources and should be undertaken only in rivers where other factors (e.g., temperature regime) are favorable (or can be made favorable) for recovery of species (such as the upper Sacramento). Such opportunities will be more economical where sources of dredger tailings or reservoir Delta deposits are available nearby.

While recognizing the navigation and flood safety issues associated with large woody debris in rivers, the importance of this debris to the foodweb and structural habitat for fish should not be overlooked. There is an opportunity to investigate ways by which to pass debris safely through dams and bridges. This may require replacing some existing bridges with those less prone to trapping woody debris.

Identify and conserve remaining unregulated rivers and streams and take actions to restore natural processes of sediment and large woody debris flux, overbank flooding, and unimpaired channel migration. Most rivers in the Central Valley are regulated by large reservoirs and therefore require considerable investment to recreate the natural processes needed to sustain true ecosystem restoration; however, a few large unregulated rivers still exist, such as the Cosumnes River and Cottonwood Creek. Lowland alluvial rivers and streams with relatively intact natural hydrology should be identified and made a high priority for acquisition of conservation and flooding easements, setting back of levees, and other restoration actions because such actions on these rivers are likely to yield high returns in restoration of natural processes and habitats and, ultimately, fish populations.

Undertake fluviogeomorphic-ecological studies of each river before making large investments in restoration projects. River ecosystem health depends not only on the flow of water, but on the flow of sediment, nutrients, and coarse woody debris and on interactions between channels and riparian vegetation, variability in flow regime, and dynamic channel changes. It is only through interdisciplinary, watershed, and historical scale studies that the constraints and opportunities particular to each river can be understood. For example, it was only after a fluviogeomorphic study of Deer Creek that the impact of flood control actions on aquatic and



riparian habitat was recognized, a recognition that has led to a proposal for an alternative flood management approach designed to permit natural river processes to restore habitats along Lower Deer Creek.



## VISION

The vision for coarse sediment supply is to provide a sustained supply of alluvial sediments that are transported by rivers and streams and distributed to riverine bed deposits, floodplains, channel bars, riffles, shallow shoals, and mudflats, throughout the Sacramento-San Joaquin Valley, Delta, and Bay regions to contribute to habitat structure, function, and foodweb production throughout the ecosystem.

Where supplies are adequate they should be protected. Where inadequate, natural supplies should be restored where possible. Where supplies cannot be restored naturally, a feasibility analysis of artificially maintaining sediment supplies will be conducted.

In specific cases natural sediment supply can be restored by removing barriers to sediment transport. Common barriers to sediment transport in Central Valley rivers are diversion dams (e.g., Daguerre Dam on the Yuba River). In some tributary streams, small dams that no longer serve a purpose can be modified, or possibly decommissioned and removed. Dam removal allows a larger fraction of gravel to pass downstream.

Studies will be conducted to determine whether smaller reservoirs could be modified or re-operated to allow some sediment from upstream sources to pass through to the dam outlet. Sediment deposits in the upper ends of reservoirs are potential sources of sediments for introductions below dams.

In some river reaches, bank armoring could be reduced or avoided by creating unimpeded channel meander corridors using special conservation zones (e.g., erosion easements), landowner incentive programs, and strategic levee setbacks where feasible. A natural river meandering process provides much of the sediment needed to sustain the ecological health of alluvial rivers.

Where channel hardening occurs downstream of major dams, sediments stored in armored banks, bars,

and upper terraces can be moved into the active streambed to replace natural sediments blocked by the dams. Where bank and floodplain deposits along rivers below dams have become inactive from controlled flows, additional sediment can be recruited by restoring episodic floodflows. These floodflows must be of sufficient duration and magnitude (e.g., peak flows that occur every 1.5 to 2 years) to mobilize channelbed, bank, and bar sediments. This strategy would apply only to river systems that have an excess of stored channel deposits because of limited flood duration and magnitude below the dam. Such actions would be coordinated with project operations and aquatic species life-cycle requirements.

Wherever possible, the future sediment supply from the remaining nondammed tributaries should be declared a protected ecological resource of the river and Bay-Delta ecosystem. (Cottonwood Creek is a prime example of a nondammed tributary of the Sacramento River that contributes a significant proportion of the present natural sediment supply to the river). Effects on sediment supplies will be considered in evaluating potential new water supply and flood storage facilities as part of the Bay-Delta solution.

Further natural sediment supplies can be restored by expanding river access to historical floodplains during high flows. Floodplains provide fine particulate organic matter and small food particles. These particles will reenter the Delta and main rivers from overland flows that pass over and through crop stubble, grasslands, and riparian woodlands.

Levee setbacks, partial historical floodplain restoration (e.g., breaching diked tidelands) and selected Delta island levee removal strategies would provide new sources of sediment to the Central Valley floodplain. These measures, combined with increased channel roughness from marsh and riparian restoration projects, will increase the sediment-trapping efficiency of the Delta in sloughs and channels that are not essential for commercial ship and barge navigation.

Increasing the extent of the high-water floodplain of the Delta will reduce the potential for channel erosion, thereby reducing the rate of sediment loss from midchannel tule islands and shallow shoals. Larger floodplain areas along rivers would allow additional riparian vegetation to grow along the river



floodways and would enhance the formation of bank and bar deposit habitats.

Appropriate reaches of the Sacramento, San Joaquin, Merced, Mokelumne, Cosumnes, Feather, and Yuba rivers and other suitable streams, such as Cottonwood and Cache creeks, will be evaluated and, where feasible, designated for eligibility as river erosion and deposition zones, or "meander belts." Meander belts will provide an area where natural erosion and sedimentation processes can occur unimpeded (within reasonable limits) to sustain a diversity of sediment-driven habitats.

In these meander belt conservation zones, some types of agricultural production could continue. Older alluvial floodplains, unlikely to be within the eroding pathway of the river within the next 20-50 years, are ideal farming lands. Farmed areas within the estimated 20-year riverbank migration corridor could be targeted for special erosion and river floodplain easements and incentive programs. Orchardists could be compensated for loss of fruit and nut trees caused by natural bank erosion, or for permanent acquisition as river floodplain conservation areas.

## **INTEGRATION WITH OTHER RESTORATION PROGRAMS**

Protection and enhancement of sediment supplies in the rivers and Delta will involve coordination with other programs including:

- the Upper Sacramento River Fisheries and Riparian Habitat Council's efforts under the SB 1086 Program to preserve remaining riparian habitat and reestablish a continuous riparian ecosystem along the Sacramento River between Redding and Colusa,
- river corridor management plans,
- the U.S. Army Corps of Engineers Sacramento River Flood Control and Bank Protection Projects,
- San Joaquin River Riparian Habitat Restoration Program to develop and implement a plan for restoration of a continuous riparian corridor,
- gravel mine reclamation programs being initiated under the Surface Mining and

Reclamation Act by the California Department of Conservation,

- the Anadromous Fish Restoration Program's gravel replenishment program (CVPIA Subsection 3406 b13),
- small dam removal and fish ladder rehabilitation projects, and
- local bank protection and levee construction projects.

## **LINKAGE TO MULTI-SPECIES CONSERVATION STRATEGY**

After decades of cumulative impacts, the majority of Central Valley rivers have been transformed from dynamic alluvial systems capable of forming their own stream beds and bank configurations to fossilized systems confined between berms, dikes, and levees or fossilized as a result of vegetation that has encroached into the low flow channel. The loss of coarse sediments captured behind the large dams has reduced or eliminated an essential ecological ingredient required for the creation of alternate bar features and in-stream and floodplain habitat structure. This, when combined with the significant reduction in natural stream flow patterns, especially high flows, has prevented regenerative fluvial processes from promoting river recovery. Not only are the components necessary for healthy river ecosystems no longer available (sediment supplies), the natural processes are impaired or lacking (high flow regimes).

The interdependence of stream hydrology, fluvial geomorphology, coarse sediments and riparian habitats is of great relevance to protection and restoration of MSCS evaluated species. Virtually all aquatic species and many riparian species are dependent on habitats created, formed, or maintained by streamflow transport of coarse and fine sediments for nursery, foraging, resting, or reproductive areas.

The basis of the ERP, and the key to the recovery of MSCS evaluated species, is the restoration of natural ecological processes. In highly altered or developed hydrologic units, understanding the role of altered streamflow patterns and sediment availability and transport on existing habitats and species is critical to developing viable and effective restoration measures.



## LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Maintenance of natural sediment supplies in the rivers, Delta, and San Francisco Bay is closely linked to the following:

- streamflow,
- floodplain processes,
- stream meander processes,
- riparian, wetland, and aquatic habitats,

and many stressors including:

- dams,
- levees,
- bank protection,
- dredging, and
- gravel and sand mining in the floodplain.

## OBJECTIVES, TARGETS, ACTIONS, AND MEASURES

Two Strategic Objectives apply to coarse sediment supply.



The first objective for coarse sediment supply is to restore coarse sediment supplies to sediment-starved rivers downstream of reservoirs to support the restoration and maintenance of functional natural riverine habitats.

**LONG-TERM OBJECTIVE:** Implement a comprehensive sediment management plan for the Bay-Delta system that will minimize problems of reservoir sedimentation and sediment starvation, shift aggregate extraction from rivers to alternate sources, and restore continuity of sediment transport through the system to the extent feasible.

**SHORT-TERM OBJECTIVE:** Develop methods and procedures to end gravel deficits below dams and mining operations; prioritize for correcting existing streams with major deficit problems and initiate action on at least 10 streams.

**RATIONALE:** One of the major negative effects of dams is the capture of coarse sediments that naturally would pass on to downstream areas. As a result, the downstream reaches can become sediment starved, producing "armoring" of streambeds in many (but not all) rivers to the point where they provide greatly reduced habitat for fish and aquatic organisms and are largely unsuitable for spawning salmon and other anadromous fish.

This objective can be accomplished by a wide variety of means, but most obviously through artificial importation of gravel and sand. Other possible actions include: (1) explore the feasibility of passing sediment through small reservoirs; (2) remove nonessential or low-value dams; (3) eliminate instream gravel mining on channels downstream of reservoirs, and limit extraction on unregulated channels to 50% of estimated bedload supply or less (or to levels determined not to negatively impact fish and other ecological resources); (4) develop incentives to discourage mining of gravel from river channels and adjacent floodplain sites; and (5) develop programs for comprehensive sediment management in each watershed, accounting for sediment trapped by reservoirs, availability of sediment from tributaries downstream of reservoirs, loss of reservoir capacity, release of sediment-starved water downstream, channel incision and related effects, and the need for sources of construction aggregate.

**STAGE 1 EXPECTATIONS:** Sediment-starved channels in the Bay-Delta system will have been identified; strategies to mitigate sediment starvation, such as shifting mining of gravel from river channels to alternate sources, adding gravel below dams, and removing nonessential dams will have been developed; demonstration projects will have been implemented (and monitored) to mitigate sediment starvation in at least six rivers.



The second Strategic Objective for coarse sediment supply is to establish hydrologic regimes in streams, including sufficient flow timing, magnitude, duration, and high flow frequency, to maintain channel and sediment conditions supporting the recovery and restoration of native aquatic and riparian species and biotic communities.



**LONG-TERM OBJECTIVE:** For regulated rivers in the region, establish scientifically based high-flow events necessary to maintain dynamic channel processes, channel complexity, bed sediment quality, and natural riparian habitats where feasible.

**SHORT-TERM OBJECTIVE:** Through management of the reservoir pool or deliberate reservoir releases, provide a series of experimental high-flow events in regulated rivers to observe flow effects on bed mobility, bed sediment quality, channel migration, invertebrate assemblages, fish abundance, and riparian habitats over a period of years. Use the findings of these studies to reestablish natural stream processes where feasible, including restoration of periodic inundation of remaining undeveloped floodplains.

**RATIONALE:** Native aquatic and riparian organisms in the Central Valley evolved under a flow regime with pronounced seasonal and year-to-year variability. Frequent (annual or longer term) high flows mobilized gravel beds, drove channel migration, inundated floodplains, maintained sediment quality for native fishes and invertebrates, and maintained complex channel and floodplain habitats. By deliberately releasing such flows from reservoirs, at least some of these physical and ecological functions can probably be recreated. A program of such high-flow releases, in conjunction with natural high-flow events, lends itself well to adaptive management because the flows can easily be adjusted to the level needed to achieve specific objectives. However, it should be recognized that channel adjustments may lag behind hydrologic changes by years or decades, requiring long-term monitoring. Also, on most rivers, reservoirs are not large enough to eliminate extremely large, infrequent events so these will continue to affect channel form at irregular, often long, intervals; artificial high-flow events may be needed to maintain desirable channel configurations created during the natural events. This objective is similar to the previous one but differs in its focus on flows that are likely to be higher than those needed to maintain most native fish species but that are important for maintaining in-channel and riparian habitats for fish as well as other species (e.g., invertebrates, birds, mammals). Experimental flow releases also will have to be carefully monitored for negative effects, such as encouraging the invasion of unwanted non-native species.

**STAGE 1 EXPECTATIONS:** Studies should be conducted on five to 10 regulated rivers in the Central Valley to determine the effects of high-flow releases. Natural floodplains should be identified that can be inundated with minimal disruption of human activity. Where positive benefits are shown, flow recommendations should be developed and instituted where feasible.

## RESTORATION ACTIONS

The general targets are to conserve and augment the natural sediment supply by increasing the availability of upstream sediment sources on select streams, increasing the availability of sediment stored in banks and riverside floodplains, increasing the extent of natural stream bank erosion and channel migration, increasing the transport of sediment to the Delta and to spawning reaches of streams, increasing the deposition and stability of sediment within the Delta, and increasing the extent and distribution of shallow water habitats and tule-willow islands in the Delta.

In most cases the supply necessary to sustain functions and habitats for specific watersheds is not known. Preliminary targets for cubic yards of gravel needed below dams have been prescribed for selected rivers.

The following general approach includes actions that will sustain existing natural sediment sources and restore natural sources that no longer contribute to the sediment supply of rivers and the Delta.

- Protect existing natural sediment sources in river floodplains from disturbances such as bank protection, gravel mining, levees, dams, changes in streamflow, and changes to natural stream meanders.
- Artificially maintain sediment supplies below dams that block natural sediments in rivers.
- Increase the availability of sediment stored in banks and riverside floodplains by removing bank protection.
- Enhance and restore natural stream bank erosion and stream meander processes.



## MSCS CONSERVATION MEASURES

The following conservation measures are included in the Multi-Species Conservation Strategy (2000) which provide additional detail to ERP actions that would help achieve species habitat or population goals. Although the measures were developed specifically for evaluated species, some measures have direct relationships to the manner in which coarse sediment supplies influence habitat quality or have adverse effects on evaluated species.

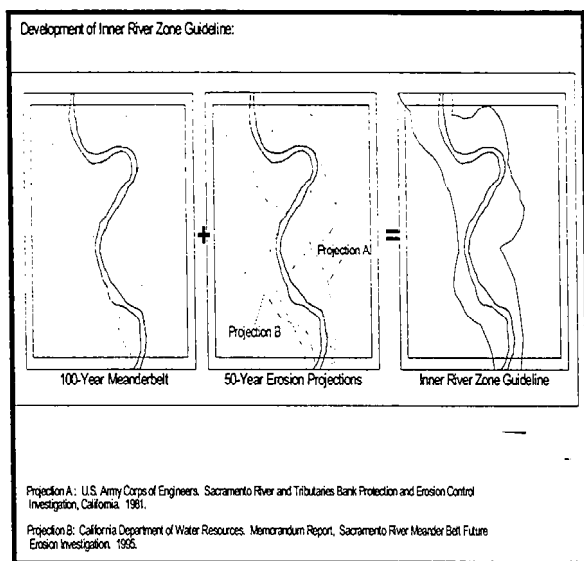
- Initial species recovery efforts should be directed to locations where there are immediate opportunities for protection, enhancement, and restoration of suitable habitats.
- Protect the Sacramento and San Joaquin river and tributary channels from physical disturbance (e.g., sand and gravel mining, diking, dredging, and levee or bank protection and maintenance) and flow disruptions (e.g., water diversion that result in entrainment and inchannel barriers or tidal gates) for the period February 1 to August 31.
- Implement management measures identified in the proposed recovery plan for the Sacramento River winter-run chinook salmon (National Marine Fisheries Service 1997).
- Implement applicable management measures identified in the restoration plan for the Anadromous Fish Restoration Program (U.S. Fish and Wildlife Service 1997) and the recovery plan for native fishes of the Sacramento-San Joaquin Delta (U.S. Fish and Wildlife Service 1996).
- Coordinate protection, enhancement, and restoration of occupied and historic habitats with other federal, state, and regional programs (e.g., the San Francisco Bay Area Wetlands Ecosystem Goals Project, the Anadromous Fish Restoration Program, and USFWS recovery plans) that could affect management of current and historic habitat use areas to avoid potential conflicts among management objectives and identify opportunities for achieving multiple management objectives.
- Modify conservation measures according to the adaptive management process as more understanding is developed of recovery needs.
- Maintain processes that support the dynamic habitat distributed throughout the species range and associated with existing populations (species this measure addresses occur on eroding margins of levees).

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## ◆ STREAM MEANDER



### INTRODUCTION

Stream meander is a dynamic natural process, and is also a term used to describe the shape of the river as a sinuous or bending wave form. Rivers with active stream channel meander zones generally support a greater diversity of aquatic and terrestrial habitats and biotic communities.

Major factors that limit natural stream channel migration include levees, bank riprap, channelization, upstream sediment loss from dams and levees, instream gravel mining, vegetation removal for increased floodway capacity or for reclamation of the river floodplain for agricultural uses and the storage of water, and release pattern from State Water Project, Central Valley Project, and other large water development projects within the Central Valley.

Approaches to restoring more natural stream meander corridors include conserving existing river migration zones, expanding stream meander corridors, conserving upstream and bank sediment supplies, and incorporating simulated flood peaks into dam water release schedules during wet years.

### RESOURCE DESCRIPTION

The width and habitat patch size of riparian forest on meandering streams tend to be large and connected. In dynamic systems, riparian forests are always being replenished by new territory colonized by cottonwood

and willow trees on recently formed point bars and floodplain deposits.

The flow velocity in meandering streams varies greatly, causing sediment and organic debris to be sorted into different sizes at different locations within the channel along a velocity gradient. Other habitat benefits from meandering streams include formation of oxbows, sloughs, and side channels that create a highly productive interaction between aquatic and terrestrial communities (e.g., canopy shading and leaf and insect drop over the riverine aquatic bed). Therefore, many species of fish, amphibians, and insects can find suitable habitat in stream meander landscapes.

Rivers that flow through their own valley alluvium (i.e., gravel, sand, and silt deposited earlier in time) have the potential to shift position. Rivers shift position when banks erode and sediment is deposited. Bank erosion and sediment deposition, form bars that block or redirect river flow. The bars also stimulate additional erosion as the river channel migrates away from the bar.

The following characteristics of a river increase the probability that it will change course during winter/spring flows:

- high average sediment or bedload source, erodible bank and bed deposits (e.g., sand and gravel),
- potential for extreme flood peaks, and
- a low density of mature vegetation along the channel.

Meandering streams typically support a wider corridor of natural habitats than channelized rivers. River flora and fauna are adapted to the changing, unstable nature of alluvial streams. Many riparian plants tolerate their stems being buried by deposits of river sediment and disperse seeds by wind and water to locations where new bars have formed. Meandering streams typically form the pool-riffle sequence that supports a range of fish habitats. The leading edge of the eroding side of the bend generates new sediment and gravel from the bank and topples riparian trees into the channel. These processes create